

Research Article

Population parameters and reproductive biology of *Otolithes ruber* (Bloch & Schneider, 1801) (Teleostei: Sciaenidae) in the northern Makran Sea

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Abstract: This study was conducted to determine some biological aspects of the tiger tooth croaker *Otolithes ruber* in the coastal waters of the northern Makran/Oman Sea. Monthly total length frequency data of *O. ruber* were collected by bottom gill-net and bottom trawl from August 2016 to August 2017. ELEFAN-I method in the software package FISAT-II was used to analyze of the length frequency data. The total length and weight relationship demonstrated that growth in this species is negative allometric. The asymptotic total length (TL_{∞}) was estimated as 60 and 65cm for males and females, respectively. The growth parameter K was calculated as 0.43 y^{-1} for males and 0.40 y^{-1} for females. The total mortality, natural mortality and fishing mortality rates were estimated as 1.85, 0.83 and 1.02 for males and 1.37, 0.77 and 0.60 for females. The exploitation rates were estimated at 0.44 for males and 0.55 for females. The sex ratio revealed that it was not a constant 1:1 throughout the year, with 58 % for females. The Gonado-Somatic Index (GSI) showed upswing trend from January to June, and the maximum GSI was 7.1 ± 0.6 in April. The recorded result showed that the tiger tooth croaker can spawn all year round and have a spawning peak from April to June (spring season). The $L_{m50\%}$ was estimated at 43.3cm of total length.

Keywords: Tiger tooth croaker, Biological aspects, Growth parameters, Oman Sea.

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Introduction

Among the various demersal fish families in Iranian waters of the Persian Gulf and the Oman Sea, the family of Scianidae has high interest amongst fishermen and fisheries managers because of the existence of several high-value commercial species, including *Protonibea diacanthus* (Lacepède, 1802), *Argyrosomus hololepidotus* (Lacepède, 1801) and *Otolithes ruber* (Bloch & Schneider, 1801). There is constituting nearly 5.0-10.5% of the total landing demersal aquatic resources in the Iranian waters (Planning & Programming Office of IFRO 2007-2016) and it consists about 0.64 and 1.82% catch

composition of fish bottom trawlers in the Persian Gulf and Oman Sea, respectively (Valinassab et al. 2006, 2016). The tiger tooth croaker inhabits in shallow coastal area down to a depth of 40m (Fischer & Bianchi 1984). In the northern Iranian waters, this species caught by a variety of fishing gear such as bottom gill-nets, bottom trawlers, hooks and as by-catch in shrimp bottom-trawl nets.

Previous studies on *O. ruber* stocks in the Iranian waters have mainly focused on growth and mortality rates (Khodadadi et al. 2010; Eskandari et al. 2012) and considering some morphometric measurements (Kazemi et al. 2013).

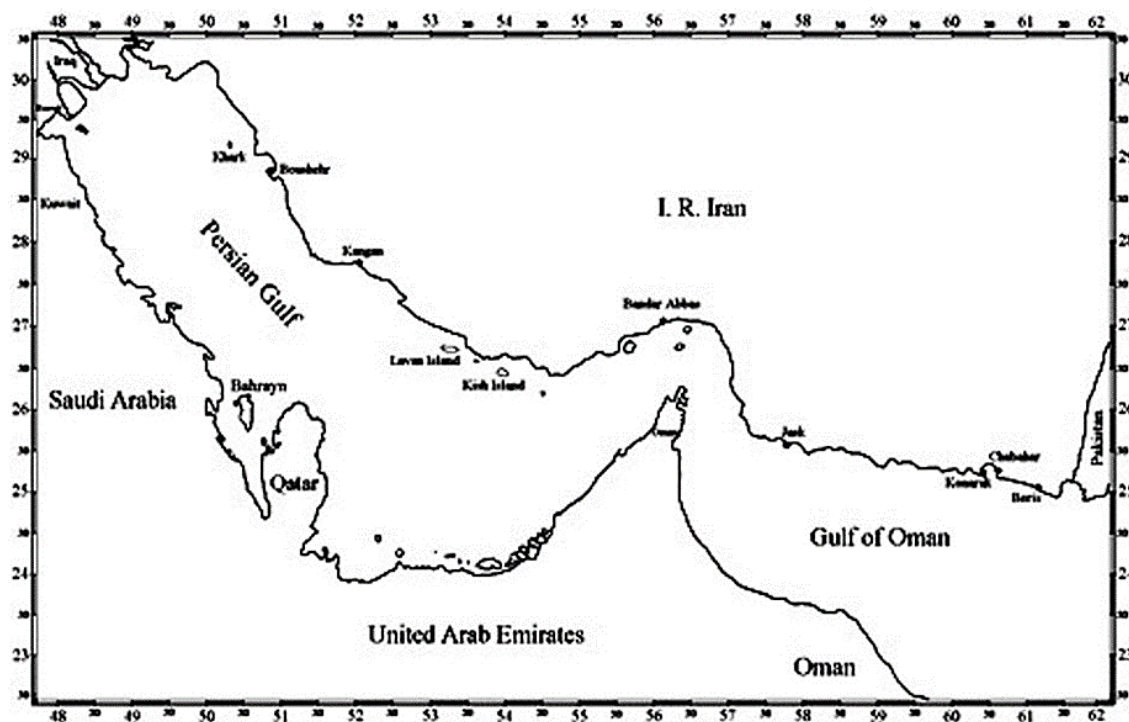


Fig.1. Study area for *Otolithes ruber* in the Makran Sea, Iran.

The present study has been undertaken to investigate the population dynamics and reproductive biology of *O. ruber* in the northern Oman Sea as the first experience time to be used for further resource management on this commercially valuable species.

Materials and Methods

Study area, sampling and measurements: Sampling was carried out using bottom gill-net with an 80mm mesh size and shrimp bottom trawling nets with a 20mm cod end mesh size. The study area was restricted in an area extending from 57°10'E to 59°05'E and the biological data were collected monthly within one year from August 2016 to August 2017 in the north-west of Oman Sea (Fig. 1). A total of 300 specimens were taken per month, each fish was measured and recorded for its sex, total length and its body weight, and reproductive aspects.

The maturity stages of ovaries were grouped into five main classes following the procedure adopted by Biswas (1993). The Gonado-Somatic Index (GSI) were calculated as following formula:

$$GSI (\%) = \frac{\text{Drained ovary weight}}{\text{Total live weight}} * 100$$

Data Analysis: Using size frequency distribution of total length, for male and female fish was depicted in each month. To establish the length-weight relationship, the commonly used relationship $W = aL^b$ was applied (Pauly 1983), Where: W is the weight (g.), L is the total length (cm), a is the intercept (condition factor) and b is the slope (growth coefficient).

A linear equation ($\ln W = \ln a + b \ln TL$) was fitted for log-transformed data. The Parameters a and b were estimated using power regression and the coefficient of determination (R^2) to show the carapace length-weight relationship. The parameter b is a shape parameter for the body form of the fish species. In theory, one might expect that the exponent b would have a value of roughly $b=3$ because the volume of a 3-dimensional object is roughly proportional to the cube of length for a regularly shaped solid. Computing b-value estimated with 3 was tested by using the t- test (Pauly 1983):

$$t = \frac{s.d(L)}{s.d(w)} \times \frac{|b-3|}{\sqrt{1-r^2}} \times \sqrt{n-2}$$

Where: s.d. (L) is the standard deviation of the ln

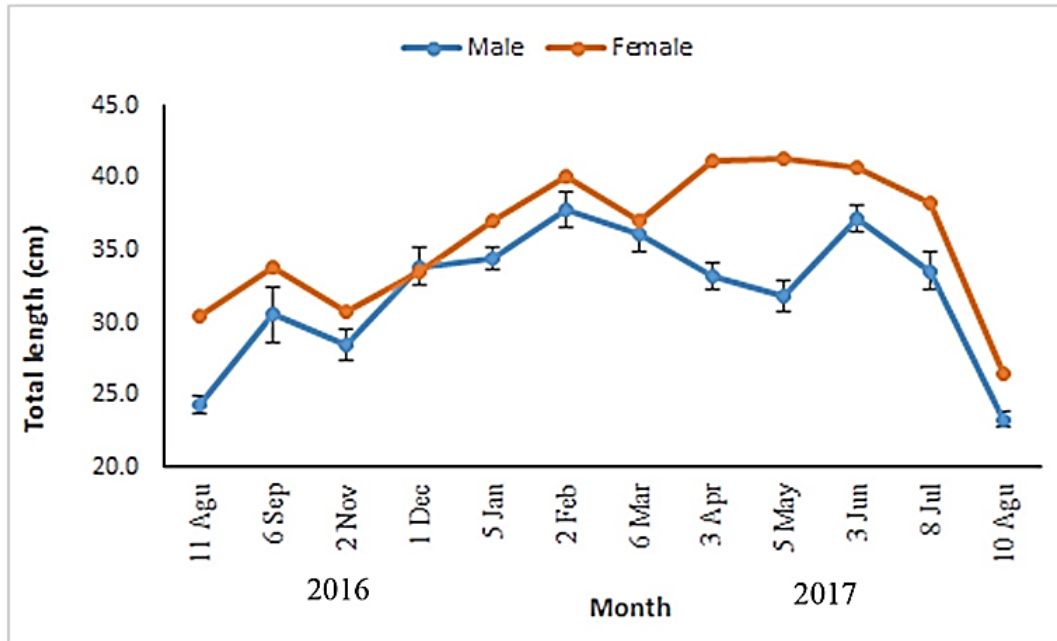


Fig.2. The changes in total length (Mean±Se) for *Otolithes ruber* in the study area.

TL values, and s.d. (*W*) the standard deviation of the $\ln W$ values, *n* being the number of fish used in the computation. The value *b* is different from 3 if *t* is greater than the table value for *t* in *n*-2 df (Pauly 1983). Input data were separated by sex and the values of *K* and *TL* ∞ were estimated for each sex using the von Bertalanffy growth equation:

$$L_t = L_\infty (1 - \exp(-K(t-t_0)))$$

Where *L_t* is the total length at time *t*, *L* ∞ is the asymptotic length (cm), *K* is the growth coefficient (Yr⁻¹), and *t*₀ is the hypothetical age when the size of the fish is zero. Using input data from length frequencies and the ELEFAN-I program, asymptotic length (*TL* ∞) and growth coefficients (*K*) were estimated for both males and females. To find the best growth curve passing through the maximum number of peaks, different starting samples and starting lengths were subjected to goodness-of-fit tests by assessing the ESP/ASP ratio (*R_n*).

In order to have a comparison between the estimated growth parameters of *O. ruber* from this study with those from other studies, Φ' (an index for the comparison of growth performance in marine animals with the von Bertalanffy type of growth) was

used. Details on growth comparison using Φ' as an index are discussed in Pauly & Munro (1984):

$$\Phi' = \text{Log}K + 2 * \text{Log}L_\infty.$$

From the estimate of growth parameters (*K*, *L* ∞), the instantaneous rate of annual total mortality (*Z*) was estimated using the length converted catch equation (Pauly 1983). The instantaneous rate of natural mortality (*M*) was obtained using Pauly's empirical formula (1980):

$$\ln M = -0.0152 - 0.279 \times \ln L_\infty + 0.6543 \times \ln K + 0.463 \times \ln T$$

Where *L* ∞ is asymptotic length (cm), *K* is the growth coefficient (Yr⁻¹) and *T* is the annual average of water temperature (°C): in the covering area in which it was 26.5°C. From estimates of the growth parameters (*K*, *L* ∞), the instantaneous rate of total mortality (*Z*) was estimated using a length-converted catch equation (Pauly 1983). In order to estimate the theoretical lifespan the (*t*_{max}) of *Otolithes ruber* was obtained using Pauly's formula (1983).

$$Tmax = \frac{3}{k} + t_0$$

Subtracting the estimates of *M* and *Z*, the instantaneous rate of fishing mortality (*F*) is given

Table 1. Total length-weight relationships of *Otolithes ruber* in the Makran Sea.

Sex	Total length-weight Equation	R ²	N	T test	Sig.
Male	W = 0. 0.0132 × CW ^{2.92}	0.96	1512	2.7	P<0.05
Female	W = 0. 0.0101 × CW ^{3.01}	0.95	2088	3.9	P<0.05
Total	W = 0. 0.0125 × CW ^{2.94}	0.91	3600	3.1	P<0.05

Table 2. Estimated growth, mortality and exploitation rates of *Otolithes ruber* in the Makran Sea.

Sex	TL _∞ (cm)	K (Y ⁻¹)	T ₀	F (Y ⁻¹)	M (Y ⁻¹)	Z (Y ⁻¹)	E
Male	60	0.43	-0.315	1.02	0.83	1.85	0.55
Female	65	0.40	-0.333	0.60	0.77	1.37	0.44
Total	65	0.41	-0.324	1.07	0.78	1.85	0.58

by:

$$F = Z - M$$

The exploitation rate $E = F/Z$. In this research, sex ratio analysis was carried out by monthly data sets of the total number of male and female fish. Chi-square (X^2) statistical was performed to test the difference between ratios in both sexes.

Spawning season of this species was forecast from the percentage of ovary stage 4 and monthly GSI index trend. The $L_{m50\%}$ was estimated by using following formula (King 2007) and least square method (Solver Tools in Microsoft Excel ver. 2013):

$$P = L / [1 + \exp(-r_m(L - L_{m50}))]$$

Where: r_m is the slope of curve, L_m is the mean total length (cm) at sexual maturity, L is mean total length (cm) and P is probability of presence mature fish.

Results

Descriptive statistics and total length-weight relationship: The total length (TL) for males and females ranged from 15 to 54cm and 18 to 57 cm, respectively (Fig. 2). The mean (\pm SE) TL was 31.78 ± 0.42 for males and 35.95 ± 0.41 cm for females. The results showed that the marketable size of males and females *O. ruber* were dominated throughout the study area with its peak during February to June. Whereas, the juvenile fishes was dominant from August to November.

The total length-weight relationship (Table 1) of

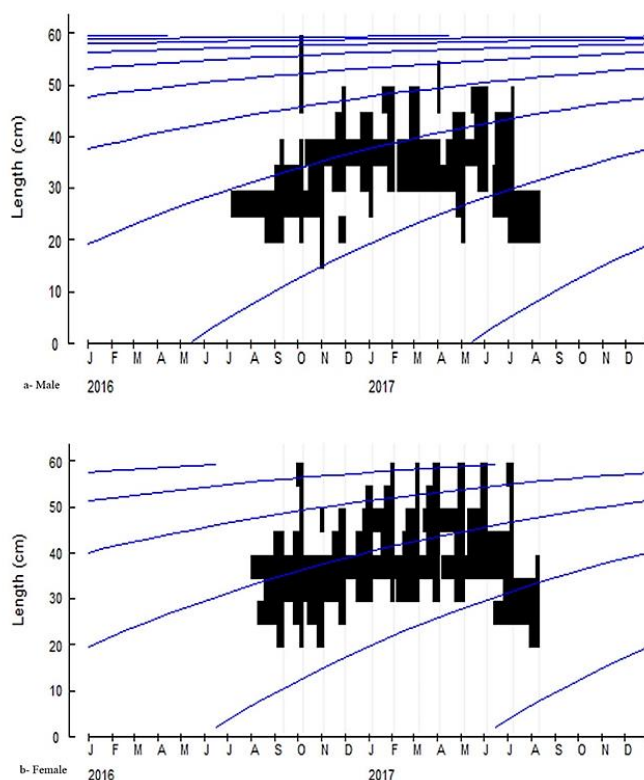


Fig.3. Monthly total length frequency distribution and growth curve in both sexes of *Otolithes ruber* in the study area.

O. ruber had a high R² value and the exponent (b=2.94) was significantly different from 3 (P<0.05), indicating that growth in this species is negatively allometric.

Growth Parameters and Performance Index (Ø): The obtained values of K were 0.43 for males and 0.40 y⁻¹ for females and, TL_∞=60 and 65cm, respectively. Table 2 shows the growth parameters

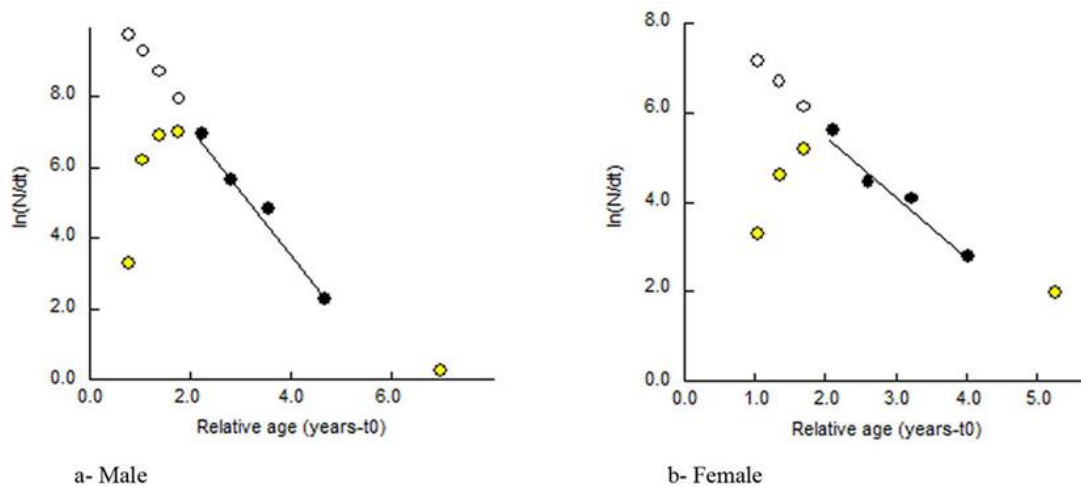


Fig.4. The length-converted catch curve of males and females *Otolithes ruber* in the study area.

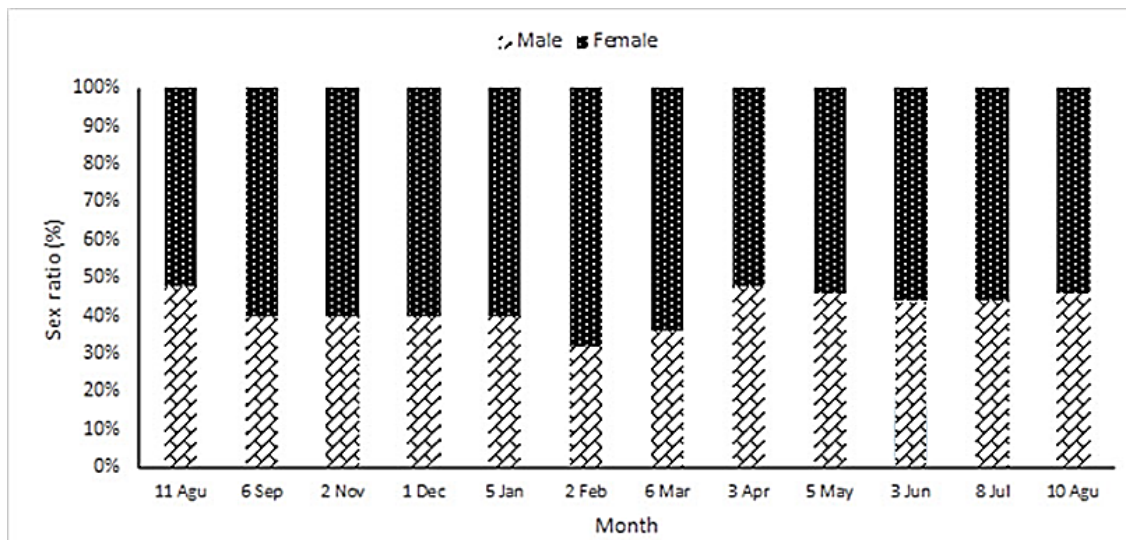


Fig.5. Sex ratio between male and female of *Otolithes ruber* from the Makran Sea, Iran.

obtained from ELEFAN-I program. Based on the obtained results, the estimated growth for this species in the coastal area was essentially independent of sex. The estimated values for the growth performance index (ϕ') of *O. ruber* during the present investigation were 3.23 for males and 3.19 for females, respectively. In this study, males and females *O. ruber* have at least three cohorts in most months of a year (Fig. 3).

Mortality and Exploitation Rate: The total mortality rates (Z) were 1.85 per year for males and 1.37 for females. The natural mortality rate (M) of *O. ruber* in the study area for each sex was calculated as 0.83, and 0.77 Yr^{-1} for males and females, respectively. The fishing mortality rate (F) was 1.02 per year for

males and 0.60 for females. The exploitation rate (E) was 0.55 for males and 0.44 for female (Table 2 and Fig. 4).

Sex-ratio: The overall sex ratio between male and female individuals of *O. ruber* throughout the year was significantly not 1:1 ($P < 0.05$), with 58% of the fish were female. An inspection of the monthly sex ratio revealed that there was also a female bias in sex ratio, but there are no significantly different in all months except from February to March (Fig. 5).

Gonad Development and Size at Sexual Maturity ($\text{LM}_{50\%}$): All five stages of the ovarian development of *O. ruber* were observed throughout the year (Fig. 6). The number of ovaries at the development stage 1 was observed only during August to December 2016

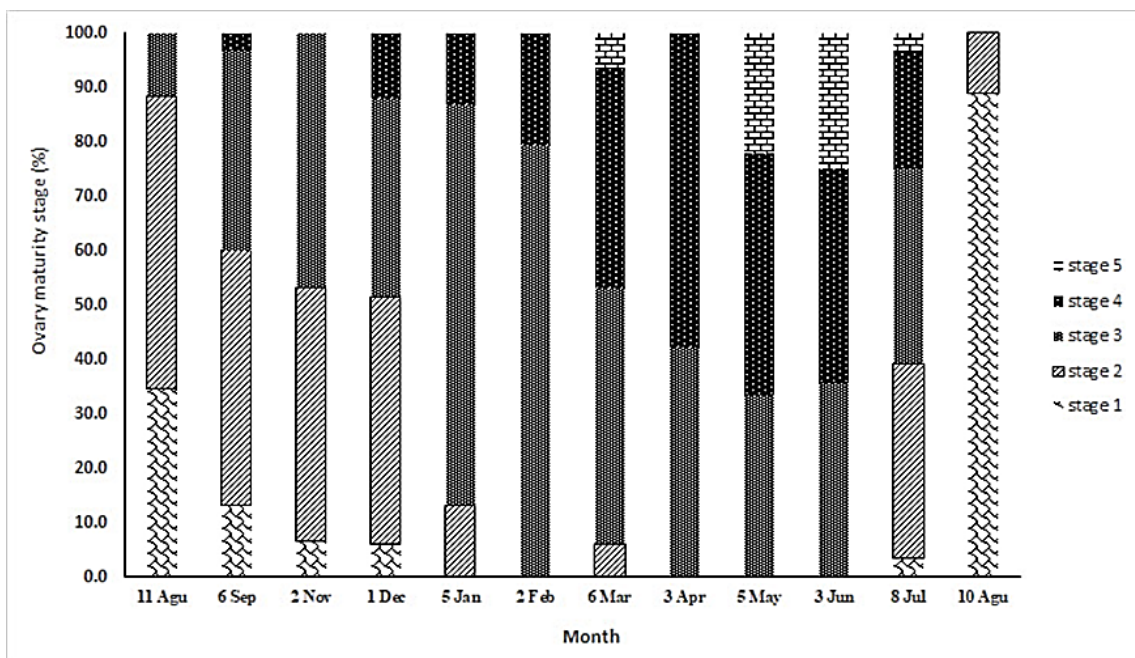


Fig.6. All maturity stages of female *Otolithes ruber* sampled from the Makran Sea, Iran.

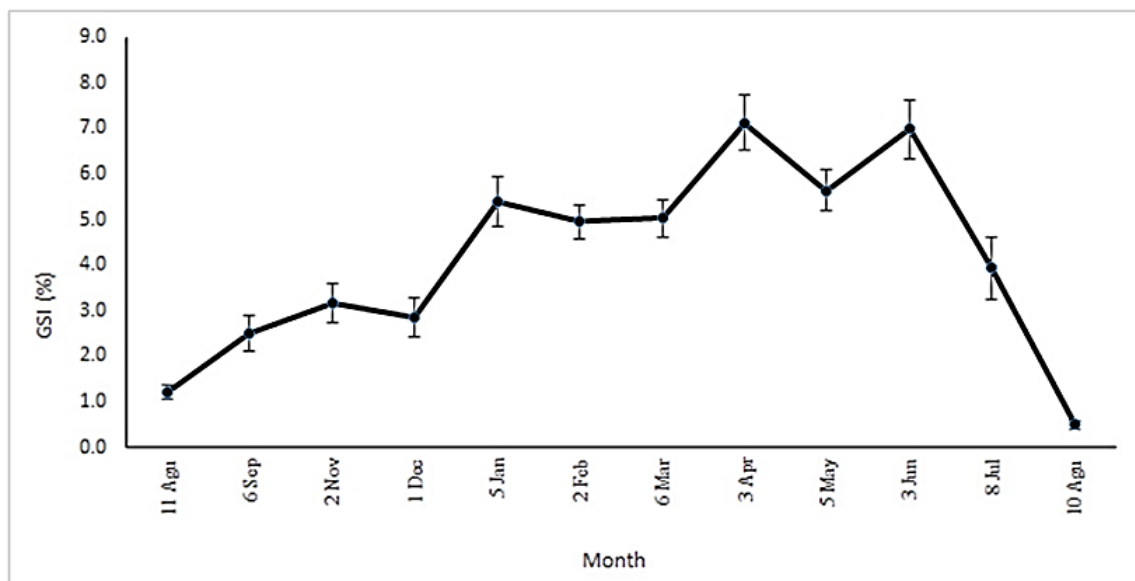


Fig.7. Monthly fluctuation GSI index of *Otolithes ruber* in the study area.

and also from July to August 2017. The recorded maturity stage 2 has relatively high percentages in study period except in March 2017 with 6.3% as well as February, April to June 2017. Also, maturity stage 3 recorded high percentages throughout the year. The highest percentage of female tiger tooth croaker in maturity stage 4 was observed from March to June 2017. The number of ovaries at the stage 5 (spent fish) was observed only during May to June in the

study period (Fig. 6). The monthly GSI estimations showed upswing trend from January to June 2017 with the maximum GSI value of 7.1 ± 0.6 observed in April 2017 (Fig. 7).

Given the percentage by month of ovary development in *O. ruber*, reveals that mature females were actively breeding throughout the year. Also, concerning the percentages of fish in maturity stage 4 and GSI value, spawning peaks were from March

Table 3. Summary of the growth and mortality parameters, Performance Index (ϕ) and exploitation rate for *Otolithes ruber* in different localities.

Species	TL ∞	K	ϕ	Z	M	F	E	Locality	Author
<i>Otolithes ruber</i>	45.9	0.32	2.84	-	-	-	-	Sofala Bank, Mozambique	Schultz 1992
<i>O. ruber</i>	59	0.38	3.13	-	-	-	-	Kuwait	Almatar 1993
<i>Otolithes cuvieri</i>	39.8	0.52	2.92	1.2	0.86	0.34	0.28	Maharashtra coast, India	Chakraborty et al. 1997
<i>O. ruber</i>	41.9	0.31	2.74	-	-	-	-	KwaZulu-Natal, South Africa	Brash and Fennessy 2005
<i>O. ruber</i>	64.58	0.4	3.22	1.95	0.7	1.25	0.64	Persian Gulf, Iran	Khodadadi et al. 2010
<i>O. ruber</i>	67.57	0.27	3.09	-	-	-	-	Persian Gulf, Iran	Eskandari et al. 2012
<i>O. ruber</i>	37.28	0.27	2.57	2.45	0.71	1.74	0.71	Thoothukudi Coast, India	Santhoshkumar et al. 2017
<i>O. ruber</i>	65	.41	3.24	1.85	0.78	1.07	0.58	Gulf of Oman, Iran	Present study

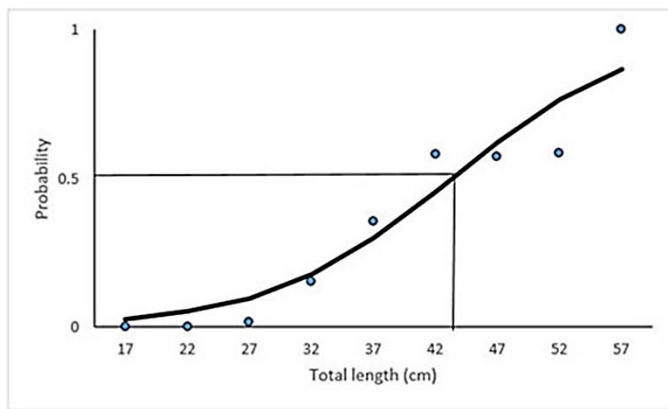


Fig.8. A logistic curve for estimation Lm50% of *Otolithes ruber* from Makran Sea, Iran.

to June (spring season).

Figure 8 shows a logistic curve fitted the estimation of length at which 50% of female fishes were in stage 4 (adult ones) with the estimated TL50%=43.3cm of total length.

Discussion

The tiger tooth croaker is one of the most important fish with high commercial value in the coastal waters of the Persian Gulf and Oman Sea; and the mean total landings of 7,163 tons during 2007-2016. The main fishing methods in the study area are bottom-gill nets, bottom-trawl, stake nets and hooks.

In the present study, the total length for *O. ruber* ranged from 15 to 57cm with the values of 31.78±0.42 and 35.95±0.41cm for males and females, respectively. Eskandari et al. (2012) measured a size range of 6-59cm for this species

landed at the northwest Persian Gulf. Also Kazemi et al. (2013) reported the size range of 22.5-58.0cm of this species for the same region. Santhoshkumar et al. (2017) reported a range of 11.2-42.5cm for the *O. ruber* at the Thoothukudi coast of India. They further reported that the small sizes represented the dominant catch in September, October and March to June, whereas the adult population were dominant throughout the study period (2006-2007) with a peak during June to December. In present study, the juvenile *O. ruber* individuals were dominant from August to November. Whereas, the adult population were found throughout the year with its peak during February to June. The abundant adult fishes were found from February to June and it might be due to the presence of mature fishes being gathered for spawning behavior. Therefore it is proposed that the best spawning season of tiger-tooth croaker is from March to June.

The length-weight relationship (LWR) is a very important tool in fisheries management. Also, length-weight relationships were used to provide the condition of fish and determine whether growth is isometric or allometric (Ricker 1975). The estimated *b*-values as *b*=2.92, 3.01 and 2.94 for males, females and total fishes, respectively derived from length-weight relationship of *O. ruber* in which was significantly different from 3, implying the allometric growth. Previous studies on *O. ruber* reported the *b*-values of 3.19 (Eskandari et al. 2012) and with a *b*=2.71 (Kazemi et al. 2013), as an

isometric growth pattern in which is not in agreement with our finding. Variation in estimated b -value from cube law reported by other authors may be due to difference in the number and ranged of size classes of samples used for t -test and also the environmental conditions of the study area. There are sometimes remarkable differences between different populations of the same species, or between the same populations in different years, presumably associated with their nutritional condition (Ricker 1975). Also, Negative allometric growth implies the fish becomes more slender as it increase in weight while positive allometric growth implies the fish becomes relatively stouter or deeper-bodied as it increases in length (Riedel et al. 2007).

The estimated growth parameters of TL_{∞} , K , T_0 for *O. ruber* in the present study were 65cm, $0.41Y^{-1}$ and -0.32 year, respectively. The TL_{∞} and K of *O. ruber* values were estimated as 64.58cm and $0.40Y^{-1}$ by Khodadadi et al. (2010) and 67.57cm and $0.27Y^{-1}$ by Eskandari et al. (2012) from the northern Persian Gulf. Studies on growth parameters of *O. ruber* from different regions have also been reported differential values (Table 3). The TL_{∞} and K values were estimated for both sexes in this study are higher than those reported from Mozambique (Schultz 1992); Kuwait (Almatar 1993); South Africa (Brash & Fennessy 2005) and India (Santhoshkumar et al. 2017). The differences in ecological conditions and latitude can have an impact on the level of value of K and L_{∞} (King 2007). The 'K' value is an indicator of physiological activity in which in this study was found to be less in *O. ruber* and thus an inverse relationship between " L_{∞} " and 'K' was evident of this claim (Sparre & Venema 1992). The length base index of growth performance (ϕ -prime) of *O. ruber* was estimated as 3.24 which are generally comparable for a species, family or similar taxonomic group in this region and other regions. The similar value of ϕ -prime was observed for the same species in different localities which ranged 2.57-3.24.

Based on length based approach, the life span of

O. ruber was estimated as 7.6 years. The similar finding of life span for *O. ruber* was reported from the KwaZulu-Natal, in African waters as 8 years. From these information, it is evident that *O. ruber* is a long lived demersal fish species.

On the other hand, total, natural and fishing mortality rates of *O. ruber* were higher for males than females. The estimated 'Z' value of *O. ruber* was reported as 1.95 from the north-west Persian Gulf (Khodadadi et al. 2010). The mortality parameters values of the present study were slightly lower than estimated values reported for the same species in Thoothukudi Coast of India (Santhoshkumar et al. 2017). Differences in mortality rates between regions might be due to environmental conditions, temperature and the occurrence of predators. Also, the exploitation rate (E) for both sexes indicates that *O. ruber* stock is currently being overexploited in the Oman Sea. The fishing mortality (1.07) of *O. ruber* was found to be higher when compared to the natural mortality (0.78) which indicates that these fishes are relatively over exploited in this region. Hence, it is proposed that the fishing effort should be decreased to get the sustainable exploitation without depletion of the stock in future.

The overall sex ratio M:F=1.0:1.38 was significantly different from the expected 1:1; and higher proportion of female's *O. ruber* being found in most of the sampling period so that a bias female frequency was significantly different from February to March. The remarkable frequency of females and especially mature females prior to their spawning season in the region (from March to June) shows that this species might be migrated towards inshore waters during the spawning season, therefore could be more accessible to the fishermen. In fishery biological investigations, the dominance of either sex may be due to schooling behaviour, differential accessibility, vulnerability, growth, maturity and mortality (Shamsul Hoda & Ajazuddin 1992).

Based on percentages of ovary in maturity stage 4 and GSI value during study period, spawning peaks were from March to June (spring season). Also, the

Lm_{50%} was estimated at 43.3cm of total length. Shamsul Hoda & Ajazuddin (1992) were reported that the *Otolithes cuvieri* had a peak of spawn from April to September in Karachi coast, Pakistan. They also reported that the size at 50% maturity in female *O. cuvieri* was occurred at 20cm in total length. Eskandari et al. (2012) found that the first maturity of *O. ruber* at 28 cm of total length in the Persian Gulf.

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مقاله پژوهشی

پارامترهای جمعیتی و زیست‌شناسی تولید مثل ماهی شوریده (ماهیان استخوانی عالی):
شوریده ماهیان در شمال دریای مکرانقاسم فرخنده^۱، محسن صفائی^{۱*}، احسان کامرانی^۱، تورج ولی نسب^۲^۱گروه شیلات، دانشگاه هرمزگان، بندرعباس، ایران.^۲پژوهشکده جنگل‌های حرا، دانشگاه هرمزگان، بندرعباس، ایران.^۳موسسه تحقیقاتی علوم شیلاتی، تهران، ایران.

چکیده: این مطالعه به منظور تعیین برخی از جنبه‌های زیست‌شناختی ماهی شوریده در آب‌های سواحل شمالی دریای مکران / عمان انجام شد. داده‌های فراوانی ماهانه طول کل ماهی *O. ruber* که با تورهای ترال کف و گوشگیر صید شده بودند در یک دوره زمانی یک‌ساله از مرداد ۱۳۹۵ تا مرداد ۱۳۹۶ ثبت شد. از روش ELEFAN-I در بسته نرم افزاری FISAT-II برای تحلیل داده‌های فراوانی طولی استفاده شد. رابطه طول و وزن نشان داد که رشد در این گونه ناهمگون منفی است. در این تحقیق طول کل بی نهایت (TL_{∞}) به ترتیب ۶۰ و ۶۵ سانتی‌متر برای جنس‌های نر و ماده برآورد شد. همچنین پارامتر رشد (K) به ترتیب برای جنس نر ۰/۴۳ و ۰/۳۷، ۱/۳۷ و ۰/۷۷ و ۰/۶۰ برای جنس ماده برآورد شد. ضریب بهره‌برداری برای جنس‌های نر و ماده به ترتیب ۰/۴۴ و ۰/۵۵ برآورد شد. نتایج مربوط به نسبت جنسی نر: ماده نشان داد که در طول سال این نسبت به طور معنی‌داری ۱:۱ نبود و ۵۸٪ ماهی‌ها را جنس‌های ماده به خود اختصاص داده بودند. شاخص Gonado-Somatic (GSI) دارای یک روند صعودی از دی ماه تا خرداد ماه بود و حداکثر GSI در ماه فروردین به میزان 0.16 ± 0.07 ثبت شد. همچنین نتایج نشان داد که ماهی شوریده می‌تواند در تمام طول سال تخم‌ریزی داشته باشد و اوج آن از فروردین تا خرداد (فصل بهار) می‌باشد. شاخص L_{m50} برای این گونه در طول کل ۴۳/۳ سانتی متر برآورد شد.

کلمات کلیدی: ماهی شوریده، جنبه‌های زیستی، پارامترهای رشد، دریای عمان.